SECTION 9C

BRIDGE DECK EVALUATION SURVEY AND GUIDELINES FOR RESTORATION WORK

1.9C.1 DECK EVALUATION SURVEY

A. Description of Survey and Testing

Testing and evaluation of concrete bridge decks consists of visual observations, delamination or debonding detection, concrete sampling for chloride analysis, and electrical potential measurement (half-cell testing). All of these bridge deck evaluation techniques are used to detect existing defects and actively deteriorating conditions of the deck. The following description is intended to provide information and procedures for these bridge deck evaluation techniques. These techniques should be used in sequence and, if warranted, in combination. By using the combined results, engineers can better evaluate the condition of any bridge deck.

1. Visual Survey

The first step for deck evaluation is a visual observation to determine the extent of spalling, cracking and scaling. Visual observation, however, does not reveal hidden structural deterioration such as delaminations or corrosion of rebars. The information from visual surveys is used to determine further deck condition survey needs. Visual surveys are generally expressed in terms of the amount of spalling and patching as a percent of the total deck area.

2. Concrete Delamination Detection (Chain Drag)

A delamination survey provides information on the subsurface condition of concrete bridge decks. A chain drag can be used to survey concrete bridge decks for delaminations.

Chain Drag: The chain drag consists of four or five segments of 25 millimeters link chain about 450 millimeters long, attached to a 600 millimeters piece of aluminum or copper tube, to which a 600 millimeters to 900 millimeters piece of tubing is attached at the midpoint, forming a "T". The chain is dragged along the surface of the concrete in a swinging motion, resulting in a ringing sound. When delaminated concrete is encountered, a noticeable "dull" sound is produced. The delaminated concrete area is outlined on the deck with chalk, crayon, or paint and can be plotted to give an overall picture of delaminated areas.

The results of the Chain Drag are not reliable when the bridge deck has been overlayed with bituminous concrete; therefore, its use is not recommended for bridge decks with bituminous concrete overlays.

3. Chloride Analysis

Chloride analysis provides a quantitative measure of the chloride ion

contamination of concrete at selected levels in the deck. Concrete samples for chloride analysis are usually taken by a rotary hammer drill. The concrete is pulverized in the hole from the combined hammering and rotating actions of the drill, thus facilitating removal and analysis. The sampling is done at or above the level of the top reinforcing bars, and the powdered concrete is collected and sent to the Department's Laboratory for analysis. The percentage of chloride ion is then calculated from the lab results. The "threshold" chloride content, or amount of chloride needed to initiate corrosion, is approximately 1.2 kilograms of chloride per cubic meter of concrete.

4. Half-Cell Test

The purpose of half-cell testing is to determine the areas in the deck in which active corrosion is present. Corrosion of the reinforcing bars in concrete decks is detected by electric current flowing from the rebar at one point (the anode) to another point (the cathode). During active corrosion, an electrical potential difference exists between the anode and cathode which can be measured by copper/copper sulfate half-cells (CSE). The CSE is pure copper rod suspended in a saturated solution of its own ions. Corrosion of the reinforcing steel can be detected by grounding the CSE to the deck slab reinforcing steel, placing the CSE in contact with the Bridge Deck Electrolyte (i.e., touching it to a small section of deck wetted with water) and measuring the electrical potential from a volt meter attached to the CSE.

Research tests have demonstrated that potential differences more negative than -0.35 volts indicates a high degree of probability of active corrosion of the reinforcing steel. Potential readings not greater than -0.20 volts indicate the probability of inactive or no corrosion, while potential readings between -0.20 volts and -0.35 volts indicate the possibility of active corrosion. The potential readings collected are then used to plot an equipotential map of the deck and to estimate the percent area of the deck with actively corroding reinforcing steel. Surveys are temperature sensitive and should only be performed if the ambient air temperature has been above 4 EC for a minimum of 72 hours immediately prior to the date of the survey.

5. Pachometer Test

In order to properly establish the deck condition, establishing the depth of cover over the top reinforcement is necessary. This will provide the evaluator with needed information to properly judge the existing condition versus what is the required minimum depth of cover.

B. Procedures to Perform Deck Evaluation Survey

1. Visual Observations

a. Make comments on the deficiencies of either the asphalt overlay or the

concrete deck wearing surface (e.g. spalling, cracking, scaling, warping, asphalt creep, alligator cracks, etc.). Include the location and size of deficiencies, if any.

b. Observe the underside of the deck and record the approximate size and location of all areas exhibiting cracks with or without efflorescence. Also, record all areas having concrete spalled from the bottom reinforcing.

c. If the structure does not have an asphalt overlay over the concrete deck, determine the percentage of spalls and/or patches in the exposed concrete deck wearing surface. Decks covered with asphalt should be similarly inspected, with a general condition statement made about the asphalt surface.

d. Record this percentage for use in the final deck condition determination.

2. Concrete Delamination Detection

Chain Drag

a. Drag the chain in a swinging motion, while walking along the concrete surface of the deck.

b. Outline, with crayon, the areas of the deck over which the chain produces a distinctive "dull" sound. These areas indicate delamination of concrete.

c. Transfer the delineated areas on the deck by plotting on a scaled map of the bridge deck.

3. Chloride Analysis

a. Select random sample locations for chloride testing using statistical methods and plot the locations on a plan view of the deck. As a minimum requirement, 10 locations per every 5000 square meter area should be tested.

b. Locate the depth of the top reinforcing steel with a pachometer to determine the chloride sampling depth.

c. Cut out an approximate 0.1 square meter section of bituminous concrete overlay, if any exists, to expose the concrete deck surface. Record the depth of overlay removed, if any.

d. Obtain each of the random samples with a rotary hammer drill. Pulverize the concrete down to within 13 millimeters of the rebar location, vacuum the hole, pulverize approximately 25 millimeters of concrete, then collect the powdered concrete sample in an uncontaminated container. All of the samples should be properly labeled and sent to the Department's Laboratory for chloride analysis.

e. After all of the holes have been drilled, and all the samples collected, refill the holes with materials similar to the material that was there prior to drilling, (i.e. concrete slabs with a fast curing "concrete compound" and asphalt overlays with asphaltic materials).

f. After the lab has analyzed the samples taken, calculate the percentage of the samples with a higher chloride content than 1.2 kilograms per cubic meter from:

$$\frac{\text{No. of Samples with Cl. greater or equal to 1.2 kg/m}^3}{\text{Total No. of Samples}} \times 100 = \_\_\%$$

4. Half-Cell Test

a. Test all equipment before proceeding to the field site. Check the Voltmeter battery for satisfactory charge.

b. Measure and mark a 1.5 meter grid pattern on the surface of the deck in accordance with Contract Plans. If a grid pattern is not shown on Contract Plans, the grid pattern should be recorded on a plan view of the deck for simplicity and speed in data recording. Start the grid with a 300 millimeter offset from curb to keep the equipment out of the dirt and debris, and an offset from the first deck joint that will allow convenient placing of the grid pattern on the deck.

c. Uncoil an ample length of wire to reach all the grid points to be tested and connect the copper sulfate half-cell (CSE) to the positive jack of the Voltmeter.

d. Pre-wet the deck at the grid points with water, saturate a sponge with water, and attach it to the bottom of the half-cell.

e. Begin to take readings of the electrical potentials at every other grid point with the half-cell and continue the testing until the whole grid pattern has been completed. The time it takes to get a stable reading will indicate the proper "soak" time for the deck. The Voltmeter needle should make an immediate response and settle down when good connections have been made. Note: If the deck is too wet or frozen, reliable readings cannot be taken.

f. After the field work is completed, the data can be recorded on graph paper and the equipotential lines plotted to produce an equipotential contour map.

g. The percentage of possible corrosion affected deck area is then calculated from the results by counting the number of tests points equal to or more negative than -0.35 volts.

$$\frac{\text{No. of Samples More Negative than -0.35 volts x 100}}{\text{Total No. of Samples}} = \_\_\%$$

5. Pachometer Survey

a. A Pachometer Survey to determine the depth of the concrete cover over the reinforcement steel. The equipment shall be calibrated according to the equipment manufacturer's specifications.

b. Locate and expose a reinforcing bar in the deck using a jackhammer. Connect the negative lead of the Voltmeter to the reinforcing steel. Connection can also be made to other metallic objects on the bridge (e.g. drainage scupper, light standards, bridge railing, expansion joints, etc.), if they are physically connected to the reinforcing steel. Connections should be made in each span if the reinforcing steel is not continuous through the expansion devices.

C. Summary - Sample Calculations and Statements

The summary calculations show a composite result of the previously described tests as follows:

1. Visual: The percentage of visual spalls over the top of the deck is 10%.

2. Concrete Delamination Detection: The analysis of the data revealed that 65% of the tested area is delaminated.

3. Chloride Analysis: The results of the chloride analysis (shown below) revealed that 60% of the samples tested were above the 1.2 kilograms per cubic meter threshold.

$$\frac{\text{Unacceptable Samples}}{\text{Total Samples}} = \frac{(6)}{(10)} = 60\%$$

4. Half-Cell Test: The results of the half-cell testing (shown below) revealed that 13.5% of the tests taken were more negative than -0.35 volts.

$$\frac{\text{Unacceptable Samples}}{\text{Total Samples}} = \frac{(13)}{(96)} = 13.5\%$$

D. Composite Results - Starting with 100% of the deck and deducting non- duplicative contaminated areas from the tests above:

Visual 100.0 - (100.0 x 0.10) = 90.0% Remaining uncontaminated

Delaminations 90.0 - (90.0 x 0.65) = 31.5% Remaining uncontaminated

Chloride 31.5 - (31.5 x 0.60) = 12.6% Remaining uncontaminated

Half-Cell 12.6 - (12.6 x 0.135)= 10.9% Remaining uncontaminated

Composite Result Final = 100.0 - 10.9 = 89.1% of the bridge deck tested had contaminated concrete.

E. CONCLUSIONS AND RECOMMENDATIONS:

The final category classification, using the percentage of bridge deck contamination shown in the summary, should be made in accordance with Subsection 1.9C.2. The classification and evaluation of the deck should also incorporate engineering judgment in addition to the test results to provide a meaningful and complete recommendation for deck rehabilitation or reconstruction.

1.9C.2 GUIDELINES FOR DETERMINING DECK CONDITION AND EXTENT OF WORK

Experience, judgment, and research have shown that deterioration often continues in partially rehabilitated decks when only the obviously deteriorated portion of the deck is removed and replaced. To minimize this effect, procedures are required that will determine the extent and type of rehabilitation or reconstruction that should be provided.

The following guidelines present procedures that should be considered in determining existing bridge deck conditions and the extent of work required for adequate rehabilitations. They also represent the current state-of-the-art on this subject and therefore will be updated as necessary when technology improves.

Although these are guidelines and are intended to be flexible, a great deal of care should be exercised in any significant deviation. In all cases, the rationale for any significant deviation should be explained in the project records or correspondence.

A. Field Condition Survey - A limited field condition survey should be made to identify bridge decks that may be structurally inadequate or possibly contaminated with de-icing chemicals such that normal maintenance is not expected to provide reasonable service. Some examples of deck slab conditions which may warrant rehabilitation and/or protective measures, are as follows:

1. Visible concrete spalls which have occurred in the deck riding surface and/or evidence of unsound concrete in the bottom exposed surface of the deck slab (which may indicate structural failure).
2. Extensive deterioration of the asphaltic overlay logically due to underlying concrete deterioration.
3. Evidence of delaminations (horizontal fracture planes) in the concrete deck.
4. Evidence of reinforcing steel corrosion.
5. Evidence of inadequate concrete cover over the reinforcing steel.

B. Structural Adequacy - When the structural adequacy of a bridge deck to carry current traffic loads is questioned, an in-depth field survey and analysis must be performed. This review should determine the extent of deficiencies as well as the feasibility of rehabilitation. Economics, traffic maintenance, etc., need to be

evaluated when balancing the feasibility of structural restoration against complete replacement.

C. Detailed Field Appraisal - Where the field condition survey has indicated that rehabilitation and/or reconstruction may be warranted, a detailed Evaluation Survey (See Subsection 1.9C.1) should be performed to further define the inadequacies of the existing deck.

This appraisal should, to the extent appropriate, consider the following as recommended components of an evaluation system:

1. Delamination detection with appropriate equipment to determine extent of internal fractures of the concrete.

2. Determination of the extent of reinforcing steel corrosion by the use of a half-cell corrosion detection device.

3. Determination of areas with inadequate concrete cover over the reinforcing steel by the use of appropriate equipment.

4. Chemical analysis to determine extent of chloride contamination.

D. Evaluation of Field Survey Results - Research reports have explained the interaction of all current detection methods and emphasized the need to use each method only for its designed purpose. The following data have been developed by research and experience:

1. Delaminations - The use of a chain drag will readily define the areas of loss of structural performance in the form of delaminations or cleavage planes within the concrete. This normally indicates active corrosion of the rebars within these areas and probable chloride contamination of the entire deck. A visible spall is the end result of delaminations at the level of the rebar.

2. Electrical Potential - Laboratory corrosion tests and field experience have shown that there is a 95 percent probability that an electrical potential in excess of -0.35 volts (CSE) to the copper-copper sulfate electrode corresponds to active corrosion in the reinforcing steel. However, this does not necessarily provide any positive relationship to the destructive nature of the corrosion that is occurring.

3. Concrete Cover - Chloride concentrations are significantly greater near the surface of a concrete bridge deck. When rebars have less than specified concrete cover they become appreciably more susceptible to damaging rebar corrosion.

4. Chloride Content - Test results have generally established that the corrosion threshold is approximately 1.2 kilograms of chloride per cubic meter of concrete at the level of the rebars for typical bridge deck

concrete.

E. Category Classification - The limits describing three categories of condition as described below are based on the best judgment available nationally.

The user will note that Category 2 will in many cases overlap Category 1. In such cases the State will exercise its best judgment based on engineering, economics and other factors to properly categorize a given bridge deck.

Category 1 - Extensive Active Corrosion

5% or more of the deck area spalled

OR

40% or more of the deck area deteriorated or contaminated as indicated by any nonduplicating combination of the following:

(1) spalls, (2) delamination, and (3) corrosion potentials more negative than -0.35 volts (CSE)

OR

40% of the area of the bridge deck indicated by random chloride sampling to contain greater than 1.2 kilograms of chloride per cubic meter of concrete at the level of the top rebars.

Category 2 - Moderate Active Corrosion

0 to 5% of the deck area spalled,

OR

5 to 40% of the deck area deteriorated or contaminated as indicated by any nonduplicating combination of the following: (1) spalls, (2) delaminations, and (3) corrosion potential more negative than -0.35 volts (CSE),

OR

5 to 40% of the area of the bridge deck indicated by random chloride sampling to contain greater than 1.2 kilograms of chloride per cubic meter of concrete at the level of the top rebars.

Category 3 - Light to No Active Corrosion

No spalls,

OR

0 to 5% of the deck area deteriorated or contaminated as indicated by any nonduplicating combination of the following: (1) delaminations, (2) corrosion potentials more negative than -0.35 volts (CSE),

OR

0 to 5% of the area of the bridge deck indicated by random chloride sampling to contain greater than 1.2 kilograms of chloride per cubic meter of concrete at the level of the top rebars.

1.9C.3 RECOMMENDED RESTORATION PROCEDURES

Based on the foregoing categorization of the condition of the bridge deck, the table below, which details rehabilitation and reconstruction alternates, has been developed.

Testing Steps:

1. Visual
2. Delamination
3. Electrical Potential
4. Pachometer Survey
5. Chloride Content

RECOMMENDED RESTORATION PROCEDURES

CATEGORY	PROCEDURES	RESTORATION (Considered Permanent)	RESTORATION (Estimated extended life 10 to 15 yrs)
Structurally		Complete Deck Replacement	

Inadequate		(Unless restorable)	
Extensive Active Corrosion (1)	Required Restoration Work	Complete Deck Replacement	Removal of all deteriorated concrete. Follow the repair procedure approved for the protective system selected.
	Testing	Steps 1 through 5 as necessary. (Probably only steps & 2)	Steps 1 & 2 only, except all the testing steps on the first five (5) bridge decks (spans) plus 10% of the remaining bridge decks.
	Suggested Protective Systems	Membrane with bituminous concrete overlay*; Concrete Overlay Protective System. *	Concrete Overlay Protective System.*
Moderate Active Corrosion (2)		Same as Category 1 above OR Same as Category 3 below, as determined by the State.	Same as Category 1
Light To No Active (3)	Required Restoration Work	Removal and Replacement of all areas of deterioration and chloride contaminated concrete as determined by corrosion potentials and/or chloride sampling. (Less than 5% of the deck area is bad).	Same as Category 1 Note: For this category of condition, permanent restoration is recommended.
	Testing	Steps 1 through 5.	Same as Category 1
	Suggested Protective System	Membrane with bituminous concrete overlay*; Concrete Overlay Protective System.*	Concrete Overlay Protective System.*

* When approved prior to Preliminary Plan

* Submission on a project to project basis.